US009066341B2

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Pan et al.

(10) **Patent No.: US 9,066,341 B2**
(45) **Date of Patent: *Jun. 23, 2015**

(54) **ADAPTIVE UPLINK/DOWNLINK TIMESLOT ASSIGNMENT IN A HYBRID WIRELESS TIME DIVISION MULTIPLE ACCESS/CODE DIVISION MULTIPLE ACCESS COMMUNICATION SYSTEM**

(71) Applicant: **InterDigital Technology Corporation**, Wilmington, DE (US)

(72) Inventors: **Kyle Jung-Lin Pan**, Saint James, NY (US); **Ariela Zeira**, Huntington, NY (US)

(73) Assignee: **InterDigital Technology Corporation**, Wilmington, DE (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **14/337,868**

(22) Filed: **Jul. 22, 2014**

(65) **Prior Publication Data**

US 2014/0334410 A1 Nov. 13, 2014

Related U.S. Application Data

(63) Continuation of application No. 12/348,637, filed on Jan. 5, 2009, now Pat. No. 8,842,644, which is a continuation of application No. 11/347,340, filed on Feb. 3, 2006, now Pat. No. 7,474,644, which is a

(Continued)

(51) **Int. Cl.**
H04J 3/24 (2006.01)
H04W 72/04 (2009.01)

(Continued)

(52) **U.S. Cl.**
CPC ***H04W 72/042*** (2013.01); ***H04W 72/0413*** (2013.01); ***H04B 7/2618*** (2013.01); ***H04W 72/082*** (2013.01)

(58) **Field of Classification Search**
CPC H04W 72/0413; H04W 72/042; H04W 72/082
USPC 370/329, 337
See application file for complete search history.

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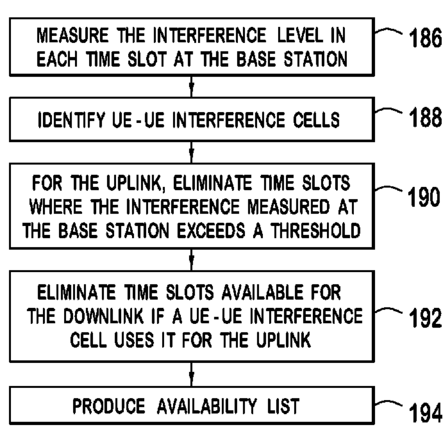
Primary Examiner — Jay P Patel
(74) *Attorney, Agent, or Firm* — Volpe and Koenig, P.C.

(57) **ABSTRACT**

A method and apparatus for adaptive uplink/downlink resource assignment may include determining uplink interference associated with each of several uplink resources. The method and apparatus may produce an uplink list with values for the uplink resources. The values may include one value indicating high interference and another value indicating low interference. The method and apparatus may compare a downlink power level to a threshold for each of the downlink resources and produce a downlink list indicating which of the downlink resources have a downlink power level which exceeds the threshold. Also, the method and apparatus may send the uplink list and downlink list. Further, the method and apparatus may receive an uplink list and a downlink list from each of several neighboring wireless network devices. The method and apparatus may assign uplink and downlink resources to a user equipment based on the uplink and downlink lists received.

10 Claims, 14 Drawing Sheets



Related U.S. Application Data

continuation of application No. 09/910,329, filed on Jul. 20, 2001, now Pat. No. 6,996,078.

(60) Provisional application No. 60/221,009, filed on Jul. 27, 2000.

(51) **Int. Cl.**

H04B 7/26	(2006.01)
H04W 72/08	(2009.01)

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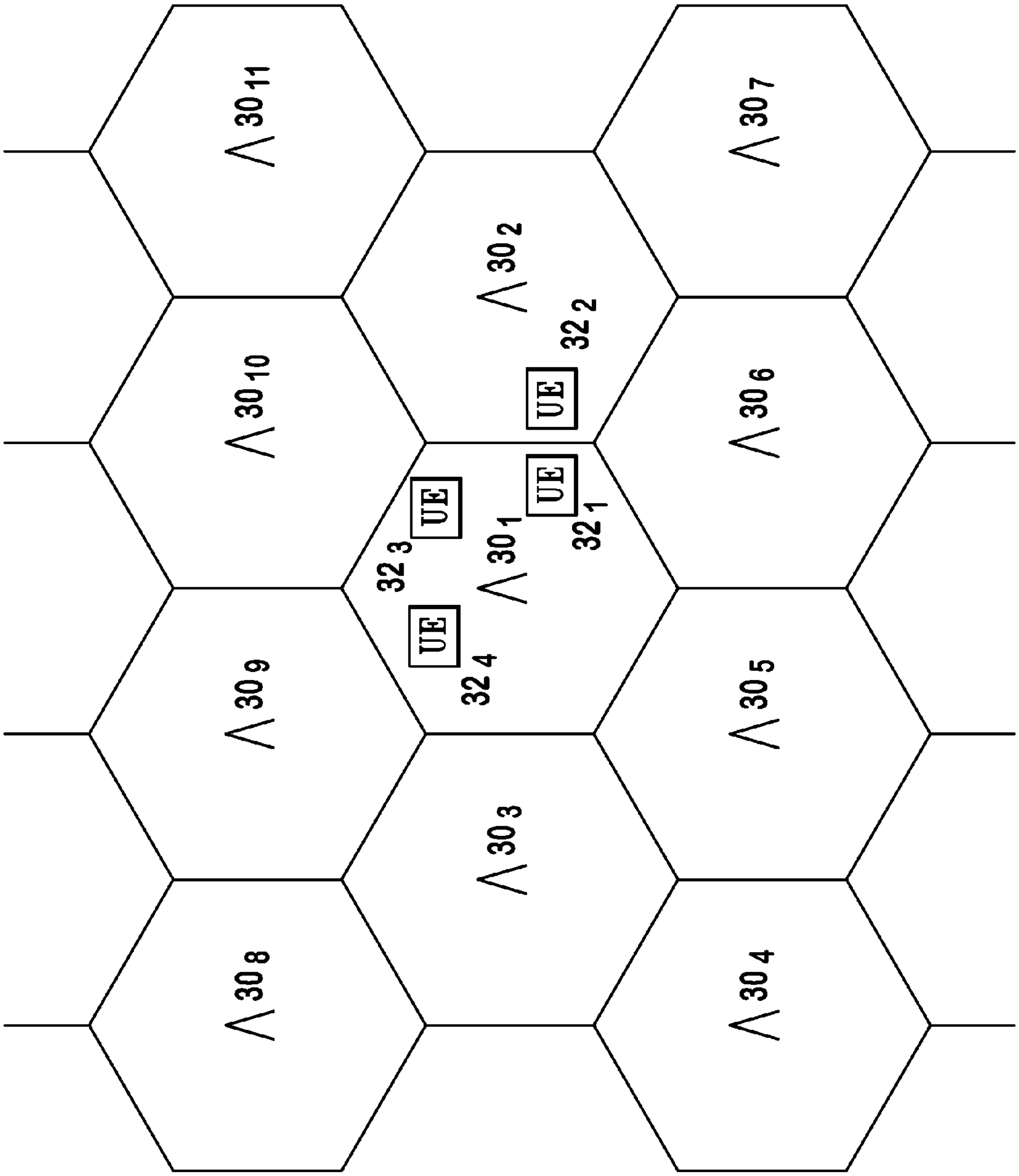

30 11
30 7
30 2
32 2
30 10
UE
30 6
UE
30 1
32 3
32 1
UE
30 9
32 4
30 5
30 3
30 8
30 4

FIG. 1

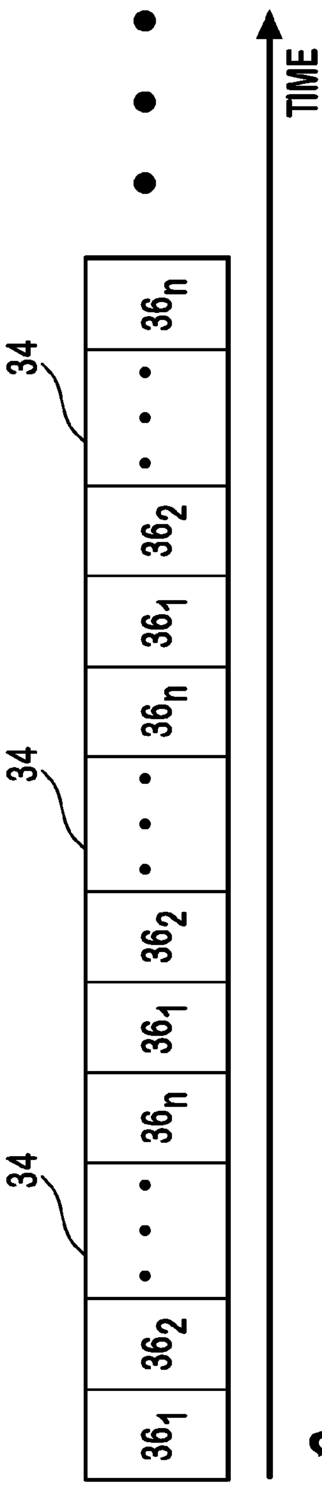

FIG. 2

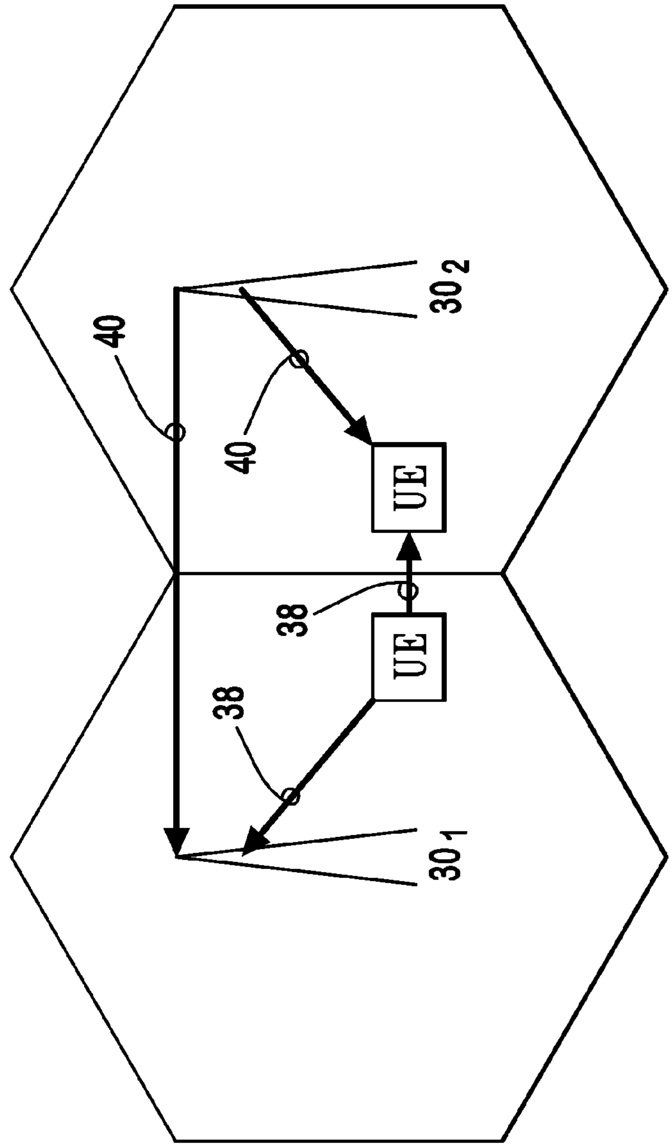

FIG. 3

76

AVAILABILITY LIST				
CELL (UPLINK / DOWNLINK)	TIME SLOT AVAILABILITY			
	S1	S2	•••	SN
1 (UPLINK)	X	X	•••	
1 (DOWNLINK)		X	•••	X
2 (UPLINK)	X	X	•••	
2 (DOWNLINK)			•••	X
⋮				
N (UPLINK)	X	X	•••	
N (DOWNLINK)		X	•••	X

FIG. 4

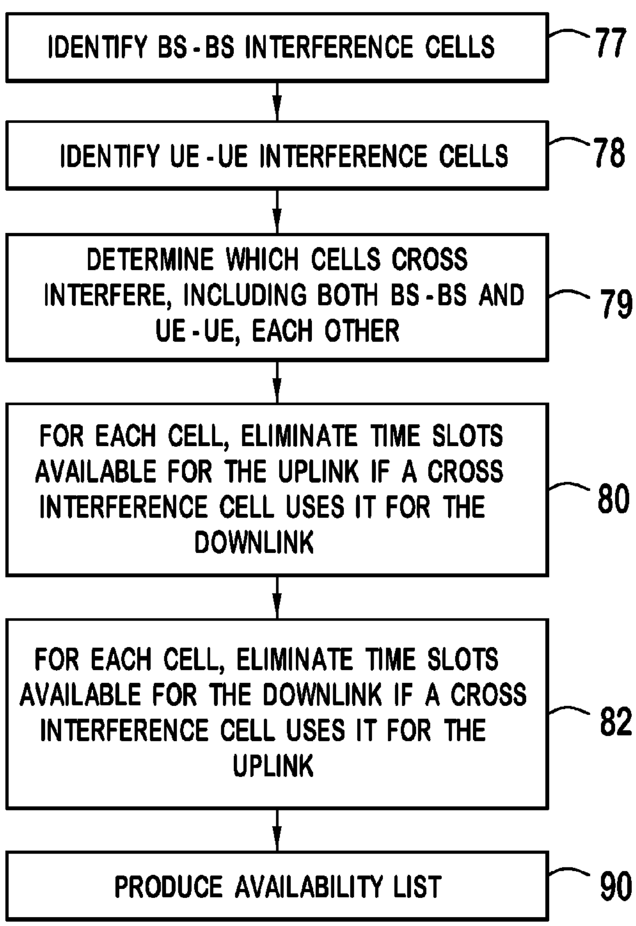

FIG. 5

84

CROSS INTERFERENCE CELL LIST											
CELL	POTENTIAL CROSS INTERFERING CELLS										
	1	2	3	4	5	6	7	8	9	10	11
1	X	I	I		I	I*			I	I	
2	I	X				I	I			I	I
3	I		X	I	I*			I	I		
4			I	X	I						
5	I		I*	I	X	I					
6	I*	I			I	X	I				
7		I				I	X				
8			I					X	I		
9	I		I					I	X	I	
10	I	I							I	X	I
11		I								I	X

FIG. 6

86

TIME SLOT ALLOCATION PER CELL															
CELL	TIME SLOT ALLOCATION														
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
1			D	U											
2	D	D							U						
3				U	D										
4										D	D				
5			D											U	
6						D									U
7										D					
8										D	D				
9						D	U								
10			D	U											
11										D	D	D	D		U

FIG. 7

88

AVAILABILITY LIST FOR CELL 1															
CELL (UPLINK / DOWNLINK)	TIME SLOT AVAILABILITY														
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
1 (UPLINK)	X	X	X		X	X									
1 (DOWNLINK)				X			X		X					X	X

FIG. 8

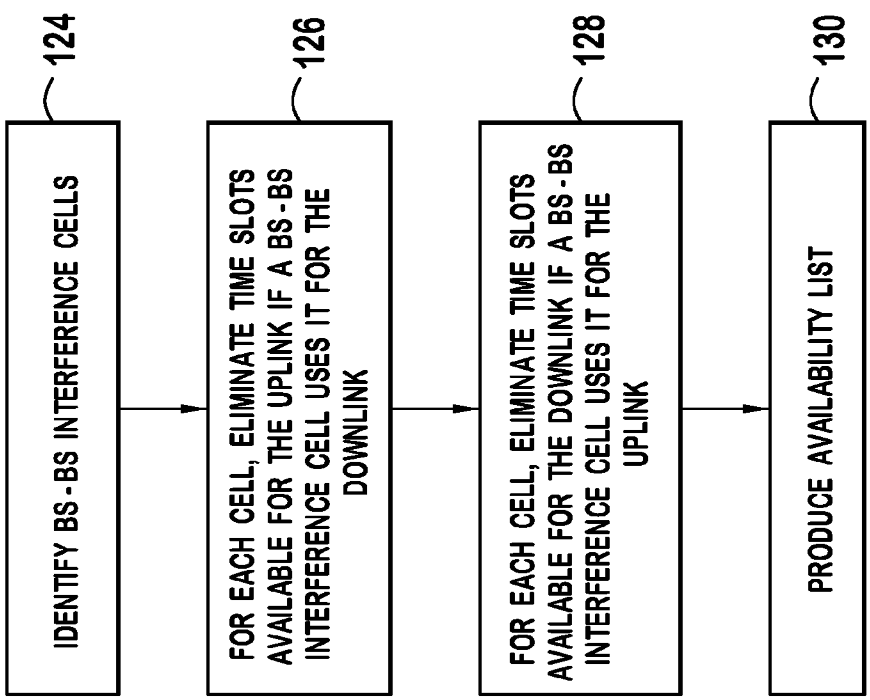
124
IDENTIFY BS-BS INTERFERENCE CELLS
126
FOR EACH CELL, ELIMINATE TIME SLOTS AVAILABLE FOR THE UPLINK IF A BS-BS INTERFERENCE CELL USES IT FOR THE DOWNLINK
128
FOR EACH CELL, ELIMINATE TIME SLOTS AVAILABLE FOR THE DOWNLINK IF A BS-BS INTERFERENCE CELL USES IT FOR THE UPLINK
130
PRODUCE AVAILABILITY LIST

FIG. 9

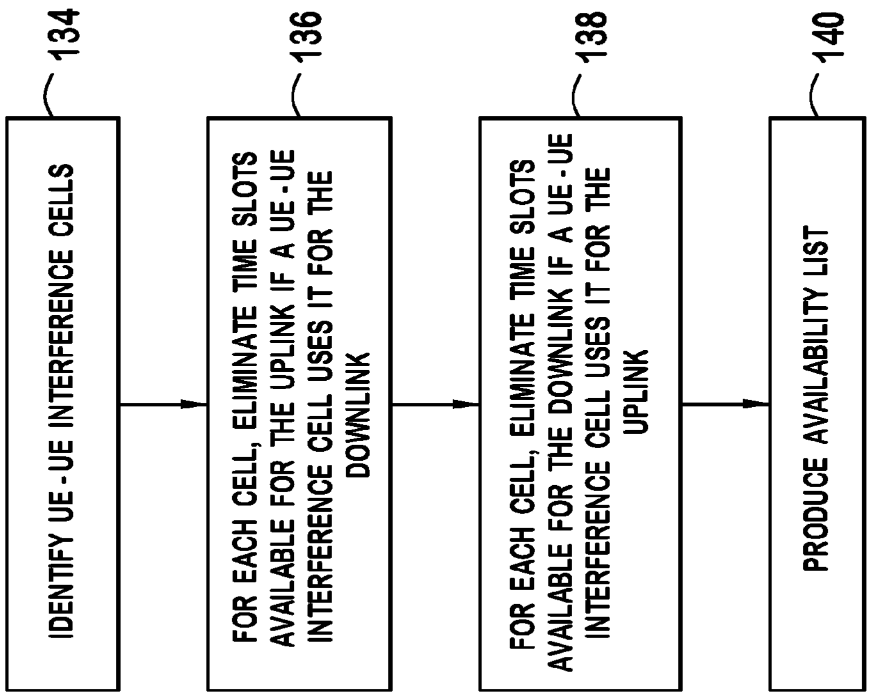
134
IDENTIFY UE-UE INTERFERENCE CELLS
136
FOR EACH CELL, ELIMINATE TIME SLOTS AVAILABLE FOR THE UPLINK IF A UE-UE INTERFERENCE CELL USES IT FOR THE DOWNLINK
138
FOR EACH CELL, ELIMINATE TIME SLOTS AVAILABLE FOR THE DOWNLINK IF A UE-UE INTERFERENCE CELL USES IT FOR THE UPLINK
140
PRODUCE AVAILABILITY LIST

FIG. 11

132

BS - BS CROSS INTERFERENCE CELL LIST											
	POTENTIAL CROSS INTERFERING CELLS										
CELL	1	2	3	4	5	6	7	8	9	10	11
1	X	I	I		I				I	I	
2	I	X				I	I			I	I
3	I		X	I				I	I		
4			I	X	I						
5	I			I	X	I					
6		I			I	X	I				
7		I				I	X				
8			I					X	I		
9	I		I					I	X	I	
10	I	I							I	X	I
11		I								I	X

FIG. 10

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UE - UE CROSS INTERFERENCE CELL LIST											
	POTENTIAL CROSS INTERFERING CELLS										
CELL	1	2	3	4	5	6	7	8	9	10	11
1	X	I*	I*		I*	I*			I*	I*	
2	I*	X				I*	I*			I*	I*
3	I*		X	I*	I*			I*	I*		
4			I*	X	I*						
5	I*		I*	I*	X	I*					
6	I*	I*			I*	X	I*				
7		I*				I*	X				
8			I*					X	I*		
9	I*		I*					I*	X	I*	
10	I*	I*							I*	X	I*
11		I*								I*	X

FIG. 12

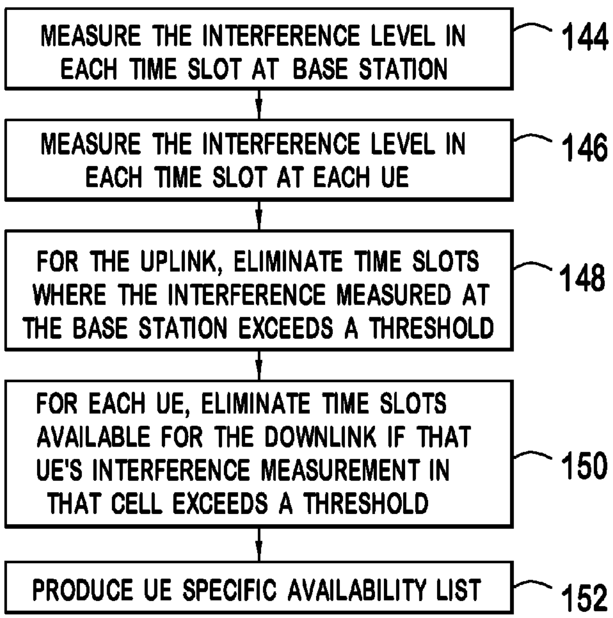

FIG. 13

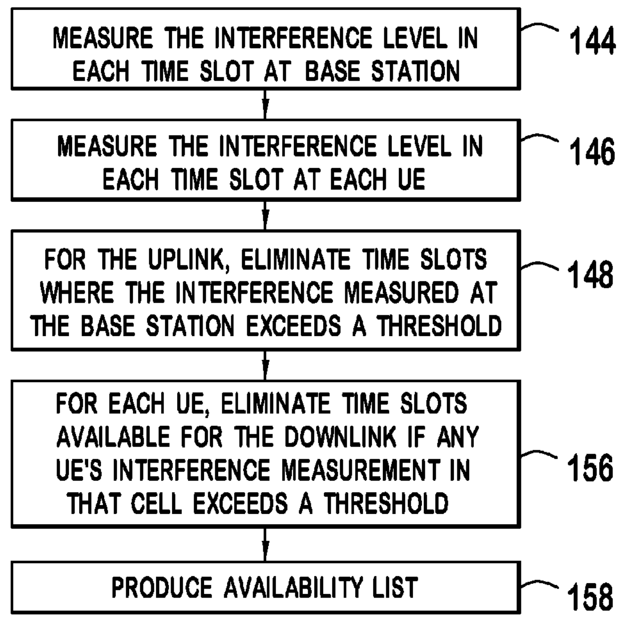

FIG. 14

154

AVAILABILITY LIST FOR CELL N															
UE IN CELL N (UPLINK / DOWNLINK)	TIME SLOT AVAILABILITY														
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
CELL (UPLINK)	X	X					X								
UE 1 (DOWNLINK)			X						X					X	X
UE 2 (DOWNLINK)									X						X
...															
UE N (DOWNLINK)						X	X	X	X						X

FIG. 15

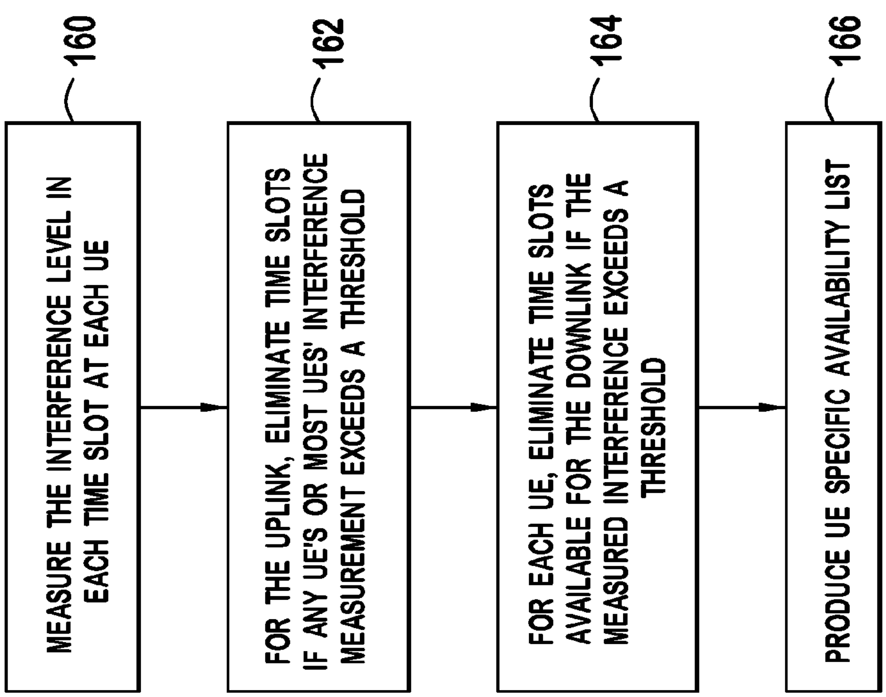
MEASURE THE INTERFERENCE LEVEL IN EACH TIME SLOT AT EACH UE
160
FOR THE UPLINK, ELIMINATE TIME SLOTS IF ANY UE'S OR MOST UES' INTERFERENCE MEASUREMENT EXCEEDS A THRESHOLD
162
FOR EACH UE, ELIMINATE TIME SLOTS AVAILABLE FOR THE DOWNLINK IF THE MEASURED INTERFERENCE EXCEEDS A THRESHOLD
164
PRODUCE UE SPECIFIC AVAILABILITY LIST
166

FIG. 16

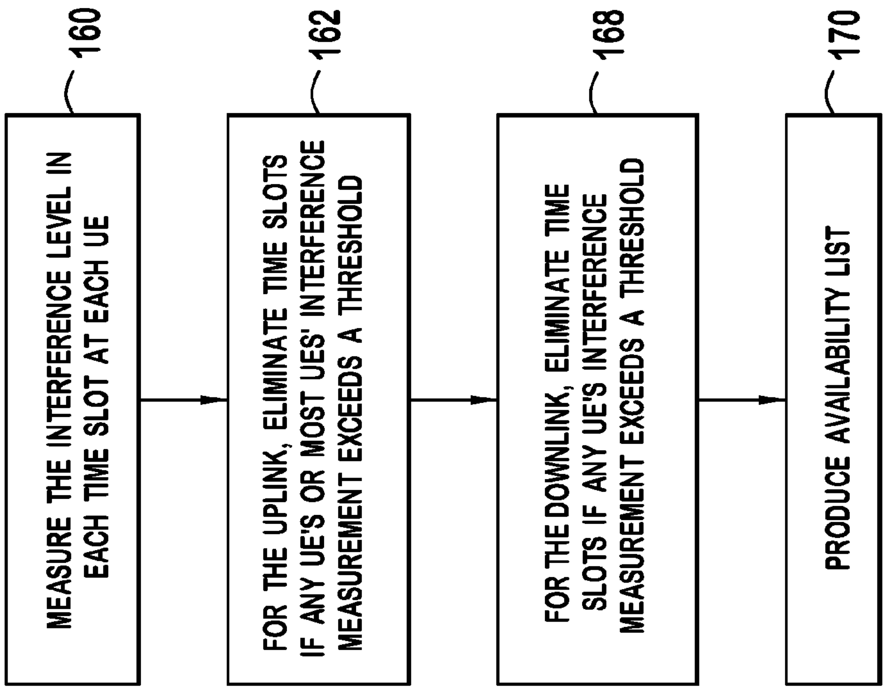
MEASURE THE INTERFERENCE LEVEL IN EACH TIME SLOT AT EACH UE
160
FOR THE UPLINK, ELIMINATE TIME SLOTS IF ANY UE'S OR MOST UES' INTERFERENCE MEASUREMENT EXCEEDS A THRESHOLD
162
FOR THE DOWNLINK, ELIMINATE TIME SLOTS IF ANY UE'S INTERFERENCE MEASUREMENT EXCEEDS A THRESHOLD
168
PRODUCE AVAILABILITY LIST
170

FIG. 17

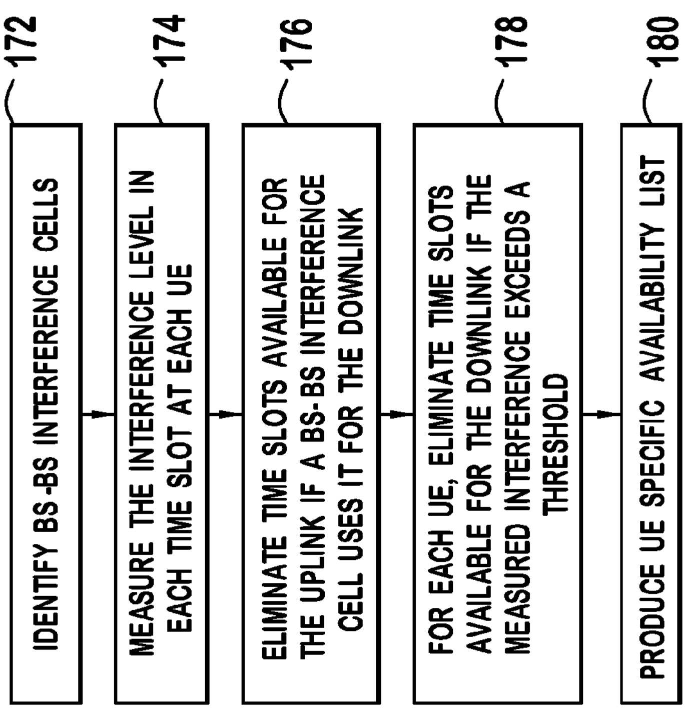
IDENTIFY BS-BS INTERFERENCE CELLS
172
MEASURE THE INTERFERENCE LEVEL IN EACH TIME SLOT AT EACH UE
174
ELIMINATE TIME SLOTS AVAILABLE FOR THE UPLINK IF A BS-BS INTERFERENCE CELL USES IT FOR THE DOWNLINK
176
FOR EACH UE, ELIMINATE TIME SLOTS AVAILABLE FOR THE DOWNLINK IF THE MEASURED INTERFERENCE EXCEEDS A THRESHOLD
178
PRODUCE UE SPECIFIC AVAILABILITY LIST
180

FIG. 18

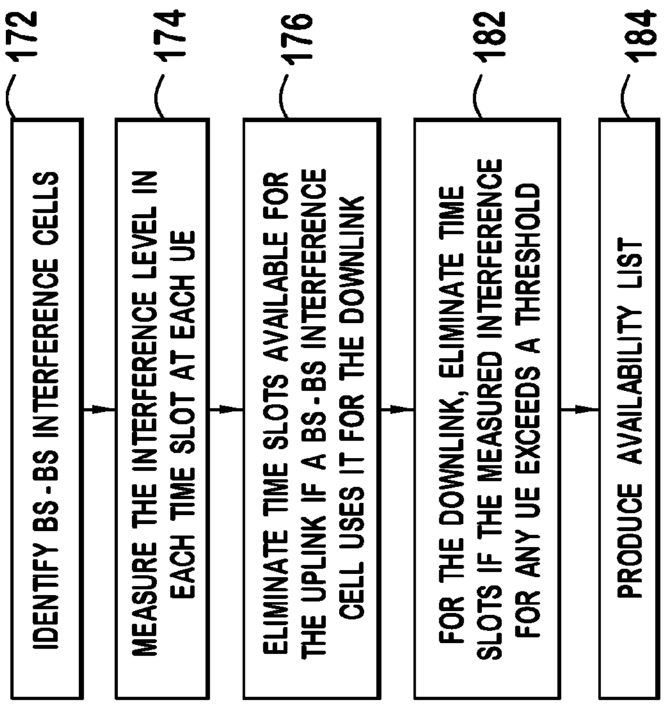
IDENTIFY BS-BS INTERFERENCE CELLS
172
MEASURE THE INTERFERENCE LEVEL IN EACH TIME SLOT AT EACH UE
174
ELIMINATE TIME SLOTS AVAILABLE FOR THE UPLINK IF A BS-BS INTERFERENCE CELL USES IT FOR THE DOWNLINK
176
FOR THE DOWNLINK, ELIMINATE TIME SLOTS IF THE MEASURED INTERFERENCE FOR ANY UE EXCEEDS A THRESHOLD
182
PRODUCE AVAILABILITY LIST
184

FIG. 19

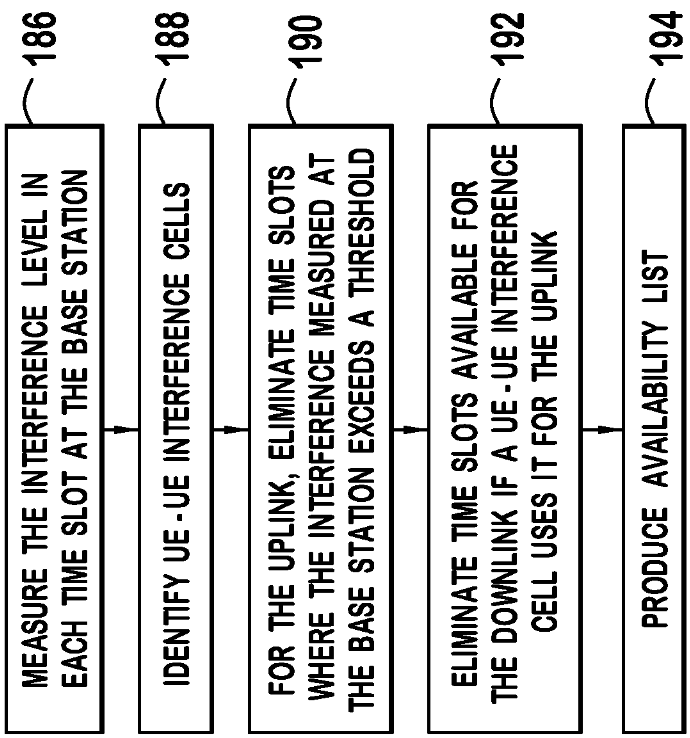
MEASURE THE INTERFERENCE LEVEL IN EACH TIME SLOT AT THE BASE STATION
186
IDENTIFY UE-UE INTERFERENCE CELLS
188
FOR THE UPLINK, ELIMINATE TIME SLOTS WHERE THE INTERFERENCE MEASURED AT THE BASE STATION EXCEEDS A THRESHOLD
190
ELIMINATE TIME SLOTS AVAILABLE FOR THE DOWNLINK IF A UE-UE INTERFERENCE CELL USES IT FOR THE UPLINK
192
PRODUCE AVAILABILITY LIST
194

FIG. 20

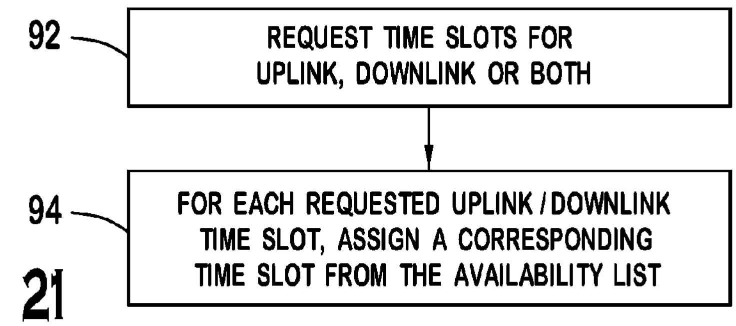
92
REQUEST TIME SLOTS FOR UPLINK, DOWNLINK OR BOTH
94
FOR EACH REQUESTED UPLINK / DOWNLINK TIME SLOT, ASSIGN A CORRESPONDING TIME SLOT FROM THE AVAILABILITY LIST

FIG. 21

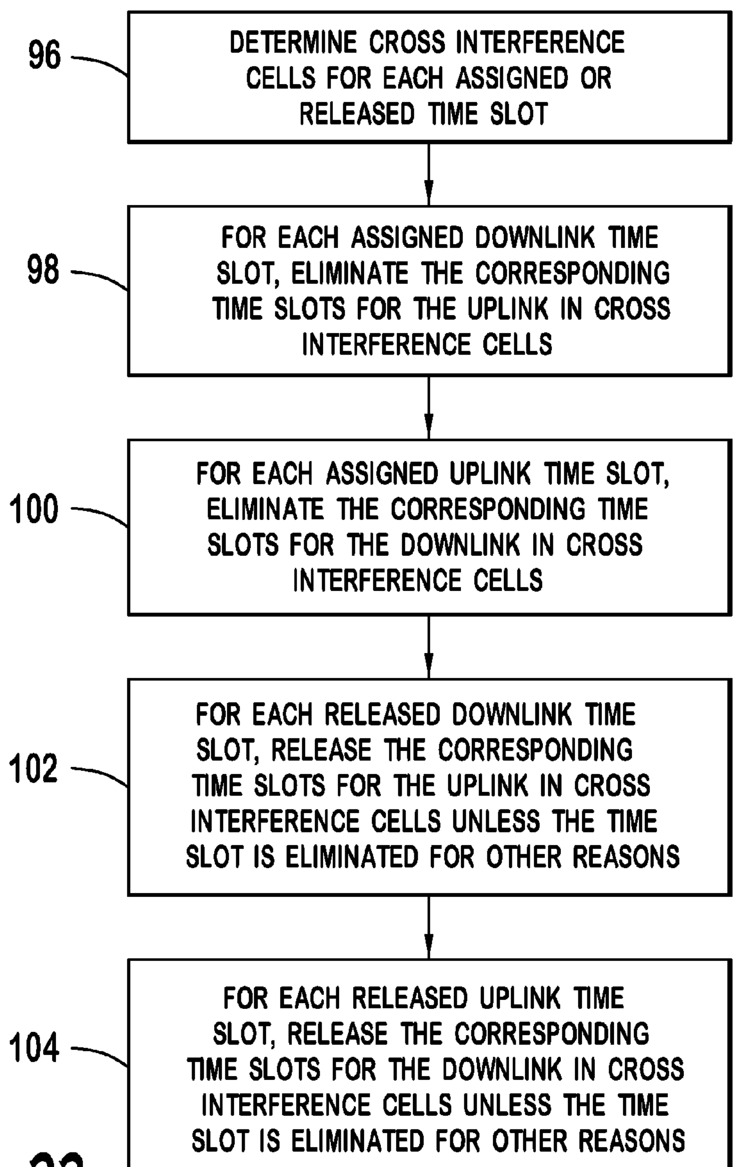
96
DETERMINE CROSS INTERFERENCE CELLS FOR EACH ASSIGNED OR RELEASED TIME SLOT
98
FOR EACH ASSIGNED DOWNLINK TIME SLOT, ELIMINATE THE CORRESPONDING TIME SLOTS FOR THE UPLINK IN CROSS INTERFERENCE CELLS
100
FOR EACH ASSIGNED UPLINK TIME SLOT, ELIMINATE THE CORRESPONDING TIME SLOTS FOR THE DOWNLINK IN CROSS INTERFERENCE CELLS
102
FOR EACH RELEASED DOWNLINK TIME SLOT, RELEASE THE CORRESPONDING TIME SLOTS FOR THE UPLINK IN CROSS INTERFERENCE CELLS UNLESS THE TIME SLOT IS ELIMINATED FOR OTHER REASONS
104
FOR EACH RELEASED UPLINK TIME SLOT, RELEASE THE CORRESPONDING TIME SLOTS FOR THE DOWNLINK IN CROSS INTERFERENCE CELLS UNLESS THE TIME SLOT IS ELIMINATED FOR OTHER REASONS

FIG. 22

106

TIME SLOT ALLOCATION PER CELL															
CELL	TIME SLOT ALLOCATION														
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
1			D	U											
2	D	D							U						
3				U	D										
4										D	D				
5			D											U	
6						D**	D*	U*							U
7										D					
8										D	D				
9						D	U								
10			D	U											
11										D	D	D	D		U

FIG. 23

108

AVAILABILITY LIST FOR CELL 7															
CELL (UPLINK / DOWNLINK)	TIME SLOT AVAILABILITY														
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
7 (UPLINK)	X	X				R	X*								
7 (DOWNLINK)								X*	X						X

FIG. 24

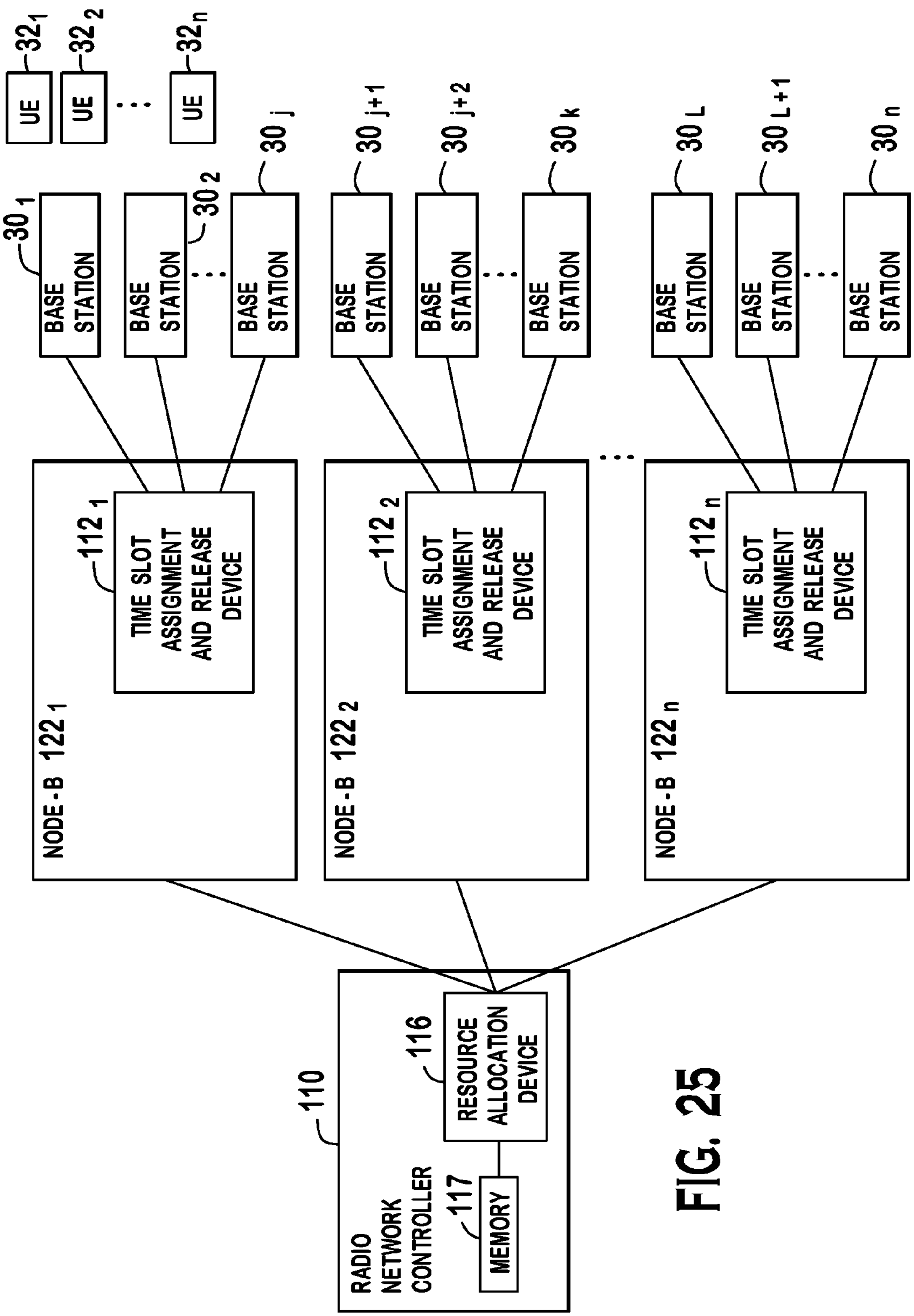
UE
32_1
UE
32_2
UE
32_n
BASE STATION
30_1
BASE STATION
30_2
BASE STATION
30_j
BASE STATION
30_{j+1}
BASE STATION
30_{j+2}
BASE STATION
30_k
BASE STATION
30_L
BASE STATION
30_{L+1}
BASE STATION
30_n
NODE - B 122_1
TIME SLOT ASSIGNMENT AND RELEASE DEVICE
112_1
NODE - B 122_2
TIME SLOT ASSIGNMENT AND RELEASE DEVICE
112_2
NODE - B 122_n
TIME SLOT ASSIGNMENT AND RELEASE DEVICE
112_n
RADIO NETWORK CONTROLLER
110
RESOURCE ALLOCATION DEVICE
116
MEMORY
117

FIG. 25

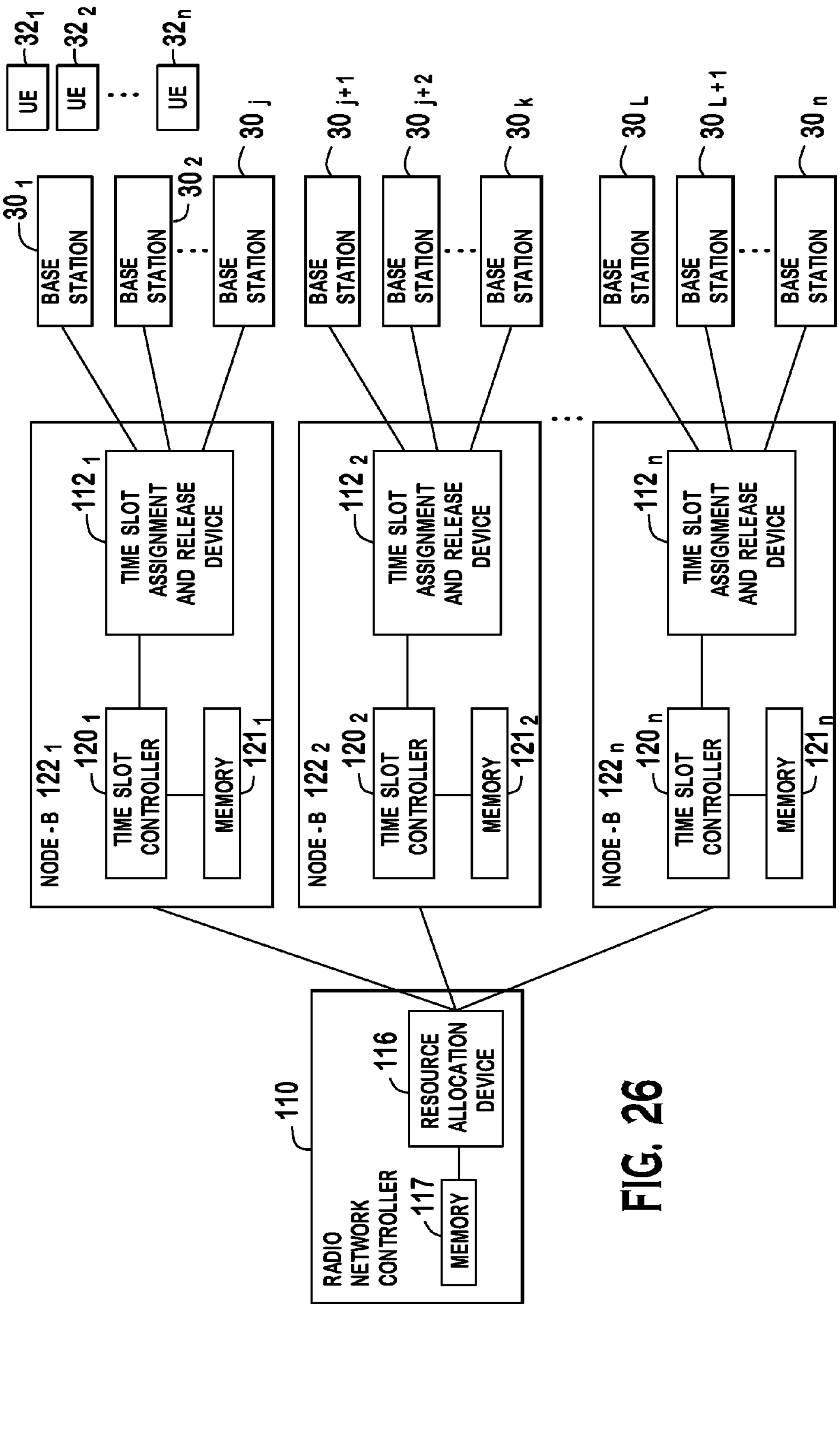
UE
UE
UE
32₁
32₂
32ₙ
BASE STATION
30₁
30₂
30ⱼ
30ⱼ₊₁
30ⱼ₊₂
30ₖ
30ₗ
30ₗ₊₁
30ₙ
TIME SLOT ASSIGNMENT AND RELEASE DEVICE
112₁
112₂
112ₙ
NODE - B 122₁
NODE - B 122₂
NODE - B 122ₙ
TIME SLOT CONTROLLER
120₁
120₂
120ₙ
MEMORY
121₁
121₂
121ₙ
RADIO NETWORK CONTROLLER
110
RESOURCE ALLOCATION DEVICE
116
MEMORY
117

FIG. 26

ADAPTIVE UPLINK/DOWNLINK TIMESLOT ASSIGNMENT IN A HYBRID WIRELESS TIME DIVISION MULTIPLE ACCESS/CODE DIVISION MULTIPLE ACCESS COMMUNICATION SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 12/348,637 filed Jan. 5, 2009, which is a continuation of U.S. patent application Ser. No. 11/347,340 filed Feb. 3, 2006, which issued as U.S. Pat. No. 7,474,644 on Jan. 6, 2009, which is a continuation of U.S. patent application Ser. No. 09/910,329 filed Jul. 20, 2001, which issued as U.S. Pat. No. 6,996,078 on Feb. 7, 2006, which claims the benefit of U.S. Provisional Application Ser. No. 60/221,009 filed Jul. 27, 2000, the contents of which are hereby incorporated by reference herein.

BACKGROUND

The present invention relates generally to resource allocation in wireless hybrid time division multiple access/code division multiple access communication systems. More specifically, the invention relates to assigning uplink and downlink timeslots in such systems.

FIG. **1** depicts a wireless communication system. The system has a plurality of base stations $\mathbf{30}_1$-$\mathbf{30}_{11}$. Each base station $\mathbf{30}_1$ communicates with user equipments (UEs) $\mathbf{32}_1$, $\mathbf{32}_3$, $\mathbf{32}_4$ in its operating area or cell. Communications transmitted from the base station $\mathbf{30}_1$ to the UE $\mathbf{32}_1$ are referred to as downlink communications and communications transmitted from the UE $\mathbf{32}_1$ to the base station $\mathbf{30}_1$ are referred to as uplink communications.

In addition to communicating over different frequency spectrums, spread spectrum code division multiple access (CDMA) systems carry multiple communications over the same spectrum. The multiple signals are distinguished by their respective chip codes (codes). To more efficiently use the spread spectrum, some hybrid time division multiple access (TDMA)/CDMA systems as illustrated in FIG. **2** use repeating frames **34** divided into a number of timeslots $\mathbf{36}_1$-$\mathbf{36}n$ such as fifteen timeslots. In time division duplex (TDD) systems using CDMA, a timeslot is used either solely for downlink or uplink communications in a cell. In such systems, a communication is sent in selected timeslots $\mathbf{36}_1$-$\mathbf{36}n$ using selected codes. Accordingly, one frame **34** is capable of carrying multiple communications distinguished by both timeslot $\mathbf{36}_1$-$\mathbf{36}_n$ and code. The use of a single code in a single timeslot with a spreading factor of sixteen is referred to as a resource unit. Based on a communication's bandwidth requirements, one or multiple resource units may be assigned to a communication.

One problem in such systems is cross cell interference as illustrated in FIG. **3**. A second cell's base station $\mathbf{30}_2$ sends a downlink communication **40** to a second cell's UE $\mathbf{32}_2$ in a certain timeslot. In the same timeslot, an uplink communication **38** is sent from a first cell's UE $\mathbf{32}_1$. The uplink communication **38** may be received by the first cell's base station $\mathbf{30}_1$ at an unacceptable interference level. Although the second cell's base station $\mathbf{30}_2$ is further away than the first cell's UE $\mathbf{32}_1$, the higher effective isotopically radiate power (EIPR) of the second cell's base station $\mathbf{30}_2$ may result in unacceptable interference at the first cell's base station $\mathbf{30}_1$.

Also shown in FIG. **3** is cross interference between UEs $\mathbf{32}_1$, $\mathbf{32}_2$. An uplink signal **38** from a first cell's UE $\mathbf{32}_1$ will create unacceptable levels of interference to a downlink communication **40** in the same timeslot received by the second cell's UE $\mathbf{32}_2$, due to their close proximity.

Accordingly, there exists a need for reducing cross cell interference.

SUMMARY

A hybrid time division duplex/code division multiple access communication system comprises a radio network controller coupled to a plurality of Node-Bs. The radio network controller comprises a resource allocation device for providing each Node-B with a list of timeslots that the Node-B can use to assign uplink timeslots and downlink timeslots. The list of timeslots does not include all potential timeslots as being assignable for uplink communications and does not include all potential timeslots as being assignable for downlink communications. Each of the plurality of Node-Bs comprises an assignment device for dynamically assigning uplink and downlink communications to users of the Node-B in response to the assignable uplink and downlink timeslots of the list.

BRIEF DESCRIPTION OF THE DRAWING(S)

FIG. **1** is a wireless spread spectrum CDMA system.

FIG. **2** illustrates timeslots in repeating frames.

FIG. **3** illustrates cross cell interference.

FIG. **4** is an availability list.

FIG. **5** is a flow chart for generating an availability list using base station to base station (BS-BS) and user equipment to user equipment (UE-UE) interference cells.

FIG. **6** is an example of a cross interference cell list.

FIG. **7** is a table showing a hypothical timeslot allocation for each cell.

FIG. **8** is an availability list for cell **1** constructed using FIGS. **6** and **7**.

FIG. **9** is a flow chart for producing an availability list using only BS-BS interference cells.

FIG. **10** is an illustration of a BS-BS cross interference list.

FIG. **11** is a flow chart for producing an availability list using only UE-UE interference cells.

FIG. **12** is a UE-UE cross interference list.

FIGS. **13** and **14** are flow charts using base station and user equipment interference measurement to determine timeslot availability.

FIG. **15** is an illustration of a user equipment specific availability list.

FIGS. **16** and **17** are flow charts for using only interference measurements to determine timeslot availability.

FIGS. **18**, **19** and **20** are flow charts for determining timeslot availability using hybrid approaches.

FIG. **21** is a flow chart of a timeslot assignment approach.

FIG. **22** is a flow chart of availability list updating.

FIG. **23** is the updated table of FIG. **7**.

FIG. **24** is an updated availability list for cell **7** based on FIG. **23**.

FIG. **25** is a centralized architecture embodiment.

FIG. **26** is a decentralized architecture embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

Although the following describes timeslot assignment in context of a TDD/CDMA system, the same timeslot elimination procedures and availability lists can be applied to a hybrid TDMA/CDMA system where uplink and downlink communications occur in the same timeslot in a cell.

FIG. **4** illustrates an availability timeslot list **76**. Along the horizontal axis, each timeslot is listed as S**1**, S**2**, . . . , SN. Along the vertical axis, each cell, listed here by the subscript of its associated base station's reference number, is listed for both the uplink and downlink. Each row indicates the timeslot availability for either the uplink or the downlink for a cell. Timeslots not available are indicated with an "X". Available timeslots are left empty.

One procedure for generating the availability list is shown in FIG. **5** and is explained in conjunction with FIGS. **6**, **7** and **8**. Initially, the cross interference between each cell pair is measured. Initially, base station $\mathbf{30}_1$-$\mathbf{30}_{11}$ to base station $\mathbf{30}_1$-$\mathbf{30}_{11}$ (BS-BS) interfering cells are determined, step **77**. BS-BS interfering cells are cells where a base station's $\mathbf{30}_1$-$\mathbf{30}_{11}$ transmissions interfere with another base station's $\mathbf{30}_1$-$\mathbf{30}_{11}$ reception.

Each cell determines its BS-BS interfering cells by estimating interference from the other cells. One approach estimates the BS-BS interfering cells using pre-measured link gains between the base stations $\mathbf{30}_1$-$\mathbf{30}_{11}$. If the estimated interference exceeds a threshold, the base stations' cells are considered BS-BS interfering cells, step **77**. Based on the threshold comparison, BS-BS interfering cells are determined and stored in a cross interference cell list **84** as illustrated in FIG. **6**. The vertical axis of the cross interference cell list **84** has each cell. The horizontal axis has potential cross interfering cells. A cell that BS-BS interferes with another cell is marked in the appropriate box by an "I", step **79**. For example, since communications in cell **2** cross interfere with cell **1**, the first row, second column box is marked with an "I." Since a cell does not interfere with itself, these boxes are marked by an "X."

Additionally, cells where UEs $\mathbf{32}_1$-$\mathbf{32}n$ may interfere with other UEs $\mathbf{32}_1$-$\mathbf{32}n$ are determined, step **78**. Due to the relatively low EIPR of UEs $\mathbf{32}_1$-$\mathbf{32}n$, the UE-UE interfering cells are in close geographic proximity, such as being adjacent. One UE's $\mathbf{32}_1$ uplink transmission can interfere with a neighboring cell's UE reception, as shown in FIG. **3**. Since cells with close geographic proximity may have UEs $\mathbf{32}_1$-$\mathbf{32}n$ which may interfere with each other, these cells are also listed as interfering cells. In FIG. **6**, the UE-UE interfering cells which were not BS-BS interfering cells are marked with an "I*", step **79**.

Using the cross interference cell list **84**, for each cell, the potential cross interference cells are determined, step **78**. For a particular cell in the vertical axis, each cell in the corresponding row marked with an "I" or "I*" is a cross interference cell. For instance, cell **1** is potentially cross interfered by cells **2**, **3**, **5**, **6**, **9** and **10**. For each cross interference cell, the timeslot allocation is determined. For instance, using the hypothetical timeslot allocation of table **86** of FIG. **7**, cell **2** is allocated downlink timeslots **1** and **2** and uplink timeslot **9**. For each downlink timeslot allocated in a cross interference cell, a corresponding uplink timeslot is eliminated, step **80**. To illustrate using FIGS. **6**, **7** and **8**, for cell **1**, cell **2**'s allocated downlink timeslot **1** eliminates timeslot **1** from cell **1**'s available uplink timeslots as shown by an "X" in cell **1**'s availability list **88** of FIG. **8**.

For each uplink timeslot allocated in a cross interference cell, a corresponding downlink timeslot is eliminated, step **82**. To illustrate for cell **1**, cell **2**'s uplink timeslot **9** eliminates that timeslot from cell **1**'s possible downlink timeslots as shown in cell **1**'s availability list **88**. After eliminating the appropriate timeslots due to the cross interference cells, an availability list **76** for each cell is produced, step **90**. As a result, uplink and downlink timeslots used in cross inference cells are made unavailable reducing cross cell interference.

To relax the assignment conditions, either only the BS-BS interfering cells or only the UE-UE interfering cells are considered. These approaches may lead to freeing up more resources for each cell. However, the looser criteria may result in unacceptable interference levels with respect to some users.

FIG. **9** is a flow chart for producing an availability list using only BS-BS interference cells. The BS-BS interference cells are identified, step **122**. A BS-BS cross interference list **132** is produced, such as in FIG. **10**. If a cell uses a timeslot for the uplink, that slot is eliminated for use by BS-BS interfering cells for the downlink, step **126**. Conversely, if a cell uses a timeslot for the downlink, that slot is eliminated for use by BS-BS interfering cells for the uplink, step **128**. A list of available timeslots is produced for each cell, step **130**. Although this approach more aggressively uses the system's resources, unacceptable downlink interference may be suffered by some users.

FIG. **11** is a flow chart for producing an availability list using only UE-UE interference cells. The UE-UE interference cells are identified, step **134**. A UE-UE cross interference list **142** is produced, such as in FIG. **12**. If a cell uses a timeslot for the uplink, that slot is eliminated for use by UE-UE interfering cells for the downlink, step **136**. Conversely, if a cell uses a timeslot for the uplink, that slot is eliminated for use by UE-UE interfering cells for the downlink, step **138**. A list of available timeslots for each cell is produced, step **140**. This approach may result in unacceptable uplink interference levels for some users.

Another approach for determining available timeslots uses interference measurements of timeslots, such as by interference signal code power (ISCP). The interference measurements may be taken at the base stations $\mathbf{30}_1$-$\mathbf{30}_{11}$, UEs $\mathbf{32}_1$-$\mathbf{32}n$ or both.

FIG. **13** is a flow chart using base station and UE interference measurements to determine available timeslots for each UE $\mathbf{32}_1$-$\mathbf{32}n$. For a particular cell, the interference level in each timeslot is measured at the base station $\mathbf{30}_1$, step **144**. Each of the cell's UEs $\mathbf{32}_1$, $\mathbf{32}_3$-$\mathbf{32}_4$ also measure interference levels in each timeslot, step **146**. The timeslot interference measurements by the base stations are used to determine the availability of uplink timeslots. The downlink timeslot availability is determined on a UE by UE basis (UE specific basis).

For the uplink, if the base station's measured interference exceeds a threshold in a timeslot, that timeslot is eliminated for the uplink, step **148**. For the downlink, each UE $\mathbf{32}_1$, $\mathbf{32}_3$, $\mathbf{32}_4$ eliminates downlink timeslots for its use, if that UE's interference measurement exceeds a threshold, step **150**. An availability list **154** is produced showing the available uplink timeslots and the available downlink timeslots for each UE as illustrated in FIG. **15**, step **152**.

Although two cells are adjacent, the location of specific UEs $\mathbf{32}_1$-$\mathbf{32}n$ in the cells may be distant. To illustrate using FIG. **1**, cell **1** and cell **2** are adjacent. However, a UE $\mathbf{32}_4$ is distant from cell **2**. Accordingly, if UE $\mathbf{32}_2$ in cell **2** uses a slot for uplink, it will most likely not interfere with the downlink reception of UE $\mathbf{32}_4$. However, UE $\mathbf{32}_2$ uplink transmissions would likely interfere with UE $\mathbf{32}_1$ downlink transmissions. As a result, a more aggressive resource allocation is available using a UE specific availability list **154**. One drawback is the increased signaling required. Due to UE mobility and other cells' reassignments, the interference measurements must be updated and signaled to the base station $\mathbf{30}_1$-$\mathbf{30}_{11}$ on a frequent basis.

FIG. **14** is a flow chart using base station and UE interference measurements to determine non-UE specific available timeslots. The base station 30_1 measures the interference in each timeslot, step **144**, and so does each UE 32_1, 32_3, 32_4, step **146**. For the uplink, if the base station measured interference exceeds a threshold in a timeslot, that timeslot is eliminated, step **148**. For the downlink, if any of that cell's UEs measured interference in a timeslot exceeds the threshold, that timeslot is eliminated for the downlink, step **156**. Using the eliminated timeslots, an availability list **88** for each cell is produced, such as per FIG. **8**. Since the UE measurements are effectively combined, missing UE interference measurements are not critical to resource unit assignment.

FIGS. **16** and **17** are flow charts using only UE interference measurements to determine available timeslots. In a cell, each UE measures the interference in each timeslot, step **160**. For the uplink, if any UE interference measurement exceeds the threshold, that timeslot is eliminated for the uplink, step **160**. Alternately, to reduce the number of eliminated uplink timeslots, only the timeslots where most of the UEs have unacceptable interference are eliminated from the uplink, step **160**. If only a few UEs report unacceptable interference, it is assumed these UEs are at the fringe of the cell and are not representative of the overall cell conditions.

Using a UE specific assignment approach as in FIG. **16**, each UE 32_1, 32_3, 32_4 has its own set of available downlink timeslots, such as per FIG. **15**. For each UE 32_1, 32_3, 32_4, a downlink timeslot is eliminated, if that UE interference measurement on the timeslot exceeds a threshold, step **164**. A UE specific availability list **150** is produced, step **166**.

A non-UE specific approach is shown in FIG. **17**. If any UE or most UEs' interference measurement exceeds a threshold in the timeslot, that timeslot is eliminated for the downlink, step **168**. An availability list **88**, such as in FIG. **8**, is produced for the entire cell.

FIGS. **18**, **19** and **20** are timeslot availability determination approaches, using hybrid BS-BS interference, UE-UE interference and interference measurement approaches. FIGS. **18** and **19** use BS-BS interference cells and UE interference measurements. The BS-BS interfering cells are determined, step **172**. Each UE 32_1, 32_3, 32_4 measures the interference in each timeslot, step **174**. For the uplink, timeslots are eliminated, if a BS-BS interfering cell uses it for the downlink, step **176**.

Downlink availability is determined on a UE by UE or a collective basis. Using a UE by UE basis per FIG. **18**, each UE 32_4, 32_3, 32_4 compares each timeslot interference measurement to a threshold. If a timeslot measurement exceeds the threshold, that timeslot is eliminated for that UE 32_4, 32_3, 32_4 in the downlink, step **178**. A UE specific availability list **150**, such as FIG. **15**, is produced, step **180**.

Using a collective basis per FIG. **19**, if any UE timeslot interference measurement exceeds a threshold, that timeslot is eliminated for the downlink for the cell, step **182**. An availability list **88**, such as FIG. **8**, is produced, step **184**.

FIG. **20** uses UE-UE interference cells and base station interference measurements. A cell's base station 30_4 measures the interference levels in each timeslot, step **186**. UE-UE interfering cells are identified, step **188**. For the uplink, eliminate uplink timeslots, if that timeslot's interference exceeds a threshold, step **190**. For the downlink, a downlink timeslot is eliminated, if a UE-UE interfering cell uses it for the uplink, step **192**. Based on the eliminated timeslots, an availability list **88**, such as FIG. **8**, is produced.

For sectored cells, the cross interference list and availability lists **84** are constructed for each sector within the cells. The cross interference between all cell's sectors is determined.

Although the following discussion focuses on non-sectorized cells, the same approach also applies to sectorized cells where the assigning is performed on a per sector basis instead of a per cell basis.

Using the availability list **76**, each base station 30_1-30_n is assigned timeslots to support its communications using the procedure of FIG. **21**. Initially, a request for an additional allocated timeslot or timeslots is made, step **92**. Referring to that base station's availability list **76**, corresponding available timeslots are assigned. To illustrate using the availability list **88** of FIG. **8**, the base station 30_1 requires both an additional allocated downlink and an uplink timeslot. The available uplink timeslots are slots **4** and **7**-**16** and the available downlink timeslots are slots **1**-**3**, **5**, **6**, **8**, **10**-**13** and **16**. One uplink timeslot and downlink timeslot will be assigned out of the corresponding available downlink and uplink timeslots. If a UE specific availability list **150** is used, the downlink assignment is based on the UE 32_1-$32n$ requiring the downlink resource unit(s).

Since the base stations 30_1-30_n need to dynamically assign and release timeslots due to varying uplink/downlink demand, the information in the availability list **76** requires updating. For approaches using interference measurements, the updates are performed by updating the measurements and the lists.

For BS-BS and UE-UE approaches, this procedure is shown in FIG. **22**. Initially, the cross interference cells are identified for each assigned or released timeslot, step **96**. For each assigned downlink timeslot, the corresponding timeslots in the cross interference cells are eliminated for the uplink, step **98**. Conversely, if the uplink timeslot is assigned, the corresponding timeslots in the cross interference cells for the downlink are eliminated, step **100**. To illustrate using FIGS. **23** and **24**, the base station 30_6 associated with cell **6** assigns timeslot **7** for the downlink, "D*", and timeslot **8** for the uplink, "U*", as indicated in table **106** of FIG. **23**. The cross interference cells are cells **1**, **2**, **5** and **7**. As shown for cell **7**'s availability list **107** of FIG. **24**, timeslot **7** is eliminated for the uplink and timeslot **8** is eliminated for the downlink, both marked as "X*".

If a downlink timeslot was released, the corresponding timeslots in the cross interference cells are freed for the uplink unless unavailable for other reasons, such as being used as a downlink timeslot in another cross interference cell, step **102**. For instance, if timeslot **6** of cell **6** is released as indicated in table **106** as "D**", cell **1**'s uplink timeslot **6** is not made available. Cell **9** is a cross interference cell to cell **1**, which also uses downlink timeslot **6**. By contrast, for cell **7**, the release of downlink timeslot **6** frees the cell for uplink communications as shown in cell **7**'s availability list **108** by an "R." If an uplink timeslot was released, the corresponding timeslots in the cross interference cells are freed for the downlink unless unavailable for other reasons, step **104**.

One approach for using uplink/downlink timeslot assignment is shown in FIG. **25** using a centralized architecture. The radio network controller (RNC) **110** has a resource allocation device **11** to assign or release a timeslot based on user demand. If assigning, the resource allocation device **116** in the RNC **110** assigns an appropriate timeslot using availability list **76**, stored in its memory **117**, per the procedure of FIG. **21**. The selected timeslots and channel codes are communicated to the base station 30_1-30_N and UEs 32_1-32_N, via the node-B timeslot assignment and release device 112_1-112_n. If releasing a timeslot, the RNC resource allocation device **116** releases that timeslot and updates the availability list **76**. Accordingly, updating of the availability list **76** is centralized by occurring at the RNC **110**.

Another approach for uplink/downlink timeslot assignment is shown in FIG. **36** using a decentralized architecture. Each node-B **122**$_1$-**122**$_N$ has its own timeslot controller **120**$_1$-**120**$_n$. When a timeslot assignment and release device **112**$_1$-**112**$_n$ requests timeslots for a communication, the node-B's timeslot controller **120**$_1$-**120**$_n$ selects an appropriate timeslot from its availability list **76**, as stored in its memory **121**$_1$. The stored availability list **76** to reduce its size may only contain the available timeslots for that node-B's cell(s). Conversely, the stored availability list **76** may contain the availability for all the RNC's cells. The decentralized approach allows for faster updates.

The selected timeslot is assigned to the communication by the timeslot assignment and release device **112**$_1$-**112***n*. To update the lists **76**, that node-B **122**$_1$-**122**$_n$updates its list **76**. The assigned and released timeslots are also sent to the RNC **110**. The RNC **110** directs the appropriate timeslot update information to the other cells. The timeslot information either contains an updated availability list **76** or merely the changes to the list **76**. If only the changes are sent, each cell's controller **120**$_1$-**120**$_n$ updates its own availability list **76** with that information. The type of timeslot information sent is based on the processing and signaling requirements of the system.

Assigning uplink/downlink timeslots is adaptable to systems supporting differing signaling rates. For systems supporting only slow network signaling, the allocated timeslot information is updated on a daily basis using a statistical analysis of the uplink/downlink demand. Since communication traffic varies during the day, a faster update rate performs better and is preferred. For medium speed network signaling, the updating is performed periodically ranging from a fraction of an hour to several hours. Medium speed network signaling also uses statistical analysis but over a shorter time period. For fast network signaling, the allocated timeslots are updated on a per call basis or frame basis. Once a timeslot is assigned or released, the appropriate lists are updated. The fast network signaling allocates timeslots on an as needed basis. As a result, it more efficiently uses the system's resources.

What is claimed is:

1. A wireless network device comprising:

a resource assignment device configured to determine an uplink interference associated with each of a plurality of uplink resources and produce an uplink list having one of a plurality of values for each of the plurality of uplink resources; wherein the plurality of values includes at least one of a first value indicating high interference and a second value indicating low interference;

the resource assignment device further configured to compare a downlink power level to a threshold for each of a plurality of downlink resources and produce a downlink list indicating for each of the downlink resources whether that downlink power level exceeds the threshold;

wherein the wireless network device sends the uplink list and the downlink list;

wherein the wireless network device receives an uplink list and a downlink list from each of a plurality of neighboring wireless network devices; and

the resource assignment device further configured to assign uplink and downlink resources to a user equipment based on the received uplink and downlink lists.

2. The wireless network device of claim **1**, wherein the uplink and downlink resources are time slots.

3. The wireless network device of claim **1**, further comprising the resources assignment device further configured to schedule resources using a decentralized architecture.

4. The wireless network device of claim **1**, wherein the wireless network device is a Node B.

5. The wireless network device of claim **1**, wherein each one of plurality of values for each of the plurality of uplink resources is determined based on a threshold comparison.

6. A method comprising:

determining, by a wireless network device, an uplink interference associated with a plurality of uplink resources;

producing, by the wireless network device, an uplink list having one of a plurality of values for each of the plurality of uplink resources; wherein the plurality of values includes at least one of a first value indicating high interference and a second value indicating low interference;

comparing, by the wireless network device, a downlink power level to a threshold for each of a plurality of downlink resources;

producing, by the wireless network device, a downlink list indicating for each of the downlink resources whether that downlink resource exceeded the threshold;

sending, by the wireless network device, the uplink list and the downlink list;

receiving, by the wireless network device, an uplink list and a downlink list from each of a plurality of neighboring wireless network devices; and

assigning, by the wireless network device, available uplink and downlink resources to a user equipment based on the received uplink and downlink lists.

7. The method of claim **6**, wherein the uplink and downlink resources are time slots.

8. The method of claim **6**, further comprising scheduling, by the wireless network device, resources using a decentralized architecture.

9. The method of claim **6**, wherein the wireless network device is a Node B.

10. The method of claim **6**, wherein each one of plurality of values for each of the plurality of uplink resources is determined based on a threshold comparison.

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